Articles

Insight on Emphysema—The First 300 Cases of Surgical Treatment

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Our experience with lung volume reduction surgery for emphysema now encompasses more than 300 cases, including several prospective trials. We have a 3.5% operative mortality rate and, with aggressive use of Heimlich valves over the past 6 months, an average hospital length of stay of 8 days. Proper patient selection is essential and can be based primarily on results of pulmonary function tests (PFTs), ventilation/perfusion (V/Q) scans, and computed tomography (CT) scans. We have found that bilateral is more effective then unilateral staple lung volume reduction surgery, which is in turn better than unilateral laser surgery. In patients with bilateral upper lobe disease, average FEV_1 (forced expiratory volume in a 1-second interval) improvement is 82%; overall, it is 61% (range –33 to 217%). We conclude that lung volume reduction surgery can be performed safely with acceptable mortality and excellent clinical results in properly selected, motivated patients.

(Fischel RJ, McKenna RJ, Gelb A, Singh N, Brenner M. Insight on emphysema: the first 300 cases of surgical treatment. West J Med 1998; 169:74–77)

Surgical therapy for emphysema, although in its infancy, has shown great promise as a treatment for selected patients with end stage bullous lung disease.[1–3] First performed in the late 1950s by Dr. Otto Brantigan,[4] the surgical approach underwent renewed popularity after initial reports from Dr. Joel Cooper in 1994 indicated a zero percent mortality rate and significant measurable improvement in pulmonary function physiology.[5] In the subsequent flurry of procedures were performed at numerous institutions in a variety of different techniques—with a wide range of morbidities, mortalities, and overall results. Many new questions arose in regard to patient selection, appropriate preoperative preparation, and choice of surgical procedure. To address some of those questions, we have performed both randomized prospective and retrospective studies comparing surgical techniques, staple line buttressing materials, and adjunctive therapeutic procedures and experiments designed to elucidate the physiologic mechanism of improvement after lung reduction surgery. Here we present the lessons learned from evaluation of more than 300 patients involved in these studies.

In every case, patients gave informed consent regarding their inclusion in the clinical trials. Each trial was approved before patient enrollment by the regulating board at the hospital where it was performed. Several of these studies have been presented in great detail elsewhere[6–9] and will be summarized here.

Operative Technique

When our surgical treatment for emphysema program was initiated (May 1994), there were two main schools of thought as to the best procedure for the disease. Unilateral laser bullectomy as popularized by Dr. A. Wakabayashi[10] had been performed on more than 500 patients, with reports of significant improvement in pulmonary function. Dr. Cooper's data[5] favored bilateral resectional therapy through a median sternotomy.

We conducted a randomized prospective trial of laser vs resectional therapy using unilateral thoracoscopic techniques. In each laser case, a contact YAG laser applied an average of 24,900 joules to the entire lung surface. In each staple case, between seven and 10 bovine pericardium–reinforced ELC 60 staple firings were applied to resect 20 to 30% of the lung in the most severely affected emphysematous areas of the worse lung. In all, 72 patients were randomly assigned to either Nd-YAG contact tip laser therapy (n = 33) or staple lung volume reduction (n = 39).

The unilateral stapling procedure achieved a significantly greater improvement in FEV_1 (forced expiratory

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TABLE 1.—*Results of Three Procedures for Lung Volume Reduction Surgery*

Procedure	n	Improvement in FEV_1 at 6 Months (%)	Patients Clinically Improved (%)	Patients With Late Pneumothorax (%)	Patients Off Oxygen (%)	Patients Off Prednisone (%)	1-Year Mortality in High-Risk Patients (%)
Unilateral Laser	33	13	24	18	52	—	—
Unilateral Staple	76	33	56	0	56*	54	17
Bilateral Staple	122	61	88	0	86*	85	1.1

*If Preoperative pO_2 > 50 mmHg on room air.

volume in a 1-second interval) than laser bullectomy. The mean improvement of patients' FEV_1 at 6 months was 0.22 L (mean ± SE, 32.9 ± 4.8%) for the staples and 0.09 L (13.4 ± 5.5% ± SE) for the laser (P = 0.01). The improvement from baseline in forced vital capacity (FVC) of the staple patients was also significant ($P < 0.006$). The mortality rate, hospital length of stay, air leak duration, operating time, and surgical take-back rate for bleeding or massive air leak were not significantly different between the two groups. On the other hand, delayed pneumothorax after hospital discharge occurred in 18% of the laser bullectomy patients compared with 0% in the staple patients ($P = 0.005$). This phenomenon has been confirmed by the work of Little et al,[1] who reported delayed pneumothorax after laser treatment in 11 of 55 patients (20%); similar results have been reported elsewhere.[2,3] The addition of laser treatment to a unilateral staple operation[2] resulted in no additional improvement in pulmonary function (FEV_1 increased 34 vs 33%, laser vs no laser).

Compared with the laser patients, a greater number of staple patients showed improvement in their dyspnea index (66 vs 24% for laser patients) (P = 0.003). At 6 months, 87.5% of staple patients had been weaned off oxygen, vs 52% of laser patients (P = 0.02). Also, a greater number of patients reported clinical improvement on a quality-of-life questionnaire administered after the staple procedure. The results of these unilateral studies, combined with the superior results Cooper reported with a bilateral staple procedure, led us to adopt the staple technique instead of the laser technique for lung volume reduction surgery.

Unilateral vs Bilateral

The next study involved 166 consecutive patients who underwent either unilateral (n = 87) or bilateral (n = 79) thoracoscopic staple lung volume reduction procedures. In this series, there was no statistically significant difference in operative mortality (3.5 vs 2.5%, respectively), mean length of stay (11.4 vs 10.9 days), or morbidity between the groups. At 6 months, 36% of the unilateral and 68% of the bilateral patients were weaned from oxygen ($P < 0.01$), and prednisone independence was achieved in 54 vs 85% ($P = 0.02$).

Bilateral thoracoscopic lung reduction achieved a mean FEV_1 improvement of 72% patients with residual volumes > 200% predicted, comparable to Cooper's series of bilateral procedures in similarly hyperinflated patients via sternotomy. Overall bilateral lung volume reduction surgery achieved a mean improvement in FEV_1 of 57% compared with 31% for unilateral reduction procedures ($P < 0.01$). Also, 44% of unilateral surgery patients had postoperative Grade 3 or 4 dyspnea compared with 12% of bilateral surgery patients. One-year mortality (including operative mortality) was 5.1% in the bilateral group and 17% in the unilateral group ($P < 0.001$). The deaths occurred primarily from respiratory failure in the high-risk unilaterally treated patients, i.e., those older than 75 years and those with preoperative $pO_2 < 50$ or $FEV_1 < 500$ mL.

Multivariant analysis of the unilateral vs bilateral groups failed to identify statistically significant differences in preoperative variables. Several highly suggestive trends did become apparent, however. Patients with hyperinflation showed more improvement in both the unilateral and bilateral groups. Patients with upper lobe disease did better than those with lower lobe disease, who did better than those with diffuse disease (target areas in multiple lobes). When operative factors were analyzed, the amount of lung resected (in grams) correlated positively with improvement in FEV_1, while dense adhesions over 50% of the thoracic space had a negative correlation with FEV_1 improvement.

Some patients achieved significant improvement with unilateral lung volume reduction surgery, but we were unable to find any preoperative factors that would have identified those patients. Because the bilateral operation results in greater overall improvement in every measurable patient parameter, and without additional morbidity and mortality, we are convinced that bilateral lung volume reduction surgery, when achievable, is the operation of choice. The significant difference in 1-year mortality rates was found to be, almost exclusively, a factor of the deaths secondary to respiratory failure in the severely compromised patients ($FEV_1 < 500$ mL, $pO_2 < 50$, age > 75) after unilateral surgery. Because the two groups were well matched by all preoperative measurements, we concluded that the bilateral procedure is especially important for those high-risk patients. The unilateral procedure is reserved for patients with contraindications to bilateral surgery, such as prior thoracotomy or pleurodesis. Results of the two studies, staple vs laser and bilateral vs unilateral, are summarized in Table 1.

Patient Selection

Patient selection is of critical importance. Commonly accepted selection criteria include the following:

1. Severe obstructive airway disease, $FEV_1 < 35\%$ despite maximal medical therapy.
2. Severe air trapping with elevated total lung capacity (TLC) and residual volume.
3. Evidence for heterogeneous bullous emphysema on CT scan, preferably upper lobe targets.

The issues of age, ambulatory status, CO_2 retention, and pulmonary artery hypertension are less clearly defined.

To further define selection criteria, we retrospectively evaluated 154 consecutive patients who underwent bilateral thoracoscopic staple lung volume reduction surgery. Our preconceived notions of acceptability influenced patient selection such that only 31% of patients evaluated (154 of 487) were accepted as surgical candidates. The reasons for rejection included lack of heterogeneous emphysema (212), medical contraindications (88), hypercapnia (20), uncontrolled anxiety or depression (10), death (2), and pulmonary artery hypertension (1).

Preoperative parameters were compared with clinical outcome (e.g., change in FEV_1, dyspnea index). We found that one of the strongest predictors of good outcome was a heterogeneous upper lobe pattern on CT and V/Q scans, with a mean improvement in FEV_1 of 68.8% vs 36.8% for lower lobe disease. Quantitative perfusion scans also played a critical role in identifying target areas of resection and determining eligibility for surgery. If no area of severe lung destruction or decreased perfusion could be identified (diffuse emphysema), the patient was deemed a nonsurgical candidate.

The retrospective study provided many other insights. First, older patients—those over age 75 treated with a bilateral operation—did very well. This is in direct contrast to the increased risk these patients encountered with a unilateral operation. None of the 17 patients ages 75 to 82 died, their mean increase in FEV_1 was 90%, and overall condition and pulmonary function improved in 14 of them. Second, 14 patients with hypercarbia (mean $pCO_2 = 60$) not only increased their FEV_1 an average of 84% but also lowered their pCO_2 to a postoperative mean of 42.8 mmHg and improved their dyspnea scale measurements from 3.4 to 2.4. These patients were selected because of the ability to decrease their CO_2 with strenuous preoperative rehabilitation, although not to levels less than 55 mmHg. Patients with very low FEV_1 (<500 mL) had an 11% operative mortality rate (five of 55), but the survivors had a mean 106% improvement in FEV_1 and a significant decrease in the dyspnea scale, from 3.18 to 1.16.

Patients with significant preoperative hypoxia ($pO_2 < 50$) had a mean increase in FEV_1 of 98% and a reduction in dyspnea scale, although nine of the 13 patients continued to require supplemental oxygen 6 months after surgery. Patients with severe hypoxemia at rest (requiring 4 L nasal cannula O_2 preoperatively) had minimal to no improvement (four of 8 patients) in dyspnea index despite a mean 60% improvement in FEV_1. All eight continued to require oxygen.

Eight patients on high-dose prednisone (>20 mg/day) had a 45% increase in FEV_1 and decreased dyspnea scale from 3.56 to 2.2.

Other Studies

The occurrence of air leaks after lung reduction remains a major source of morbidity despite the advent of buttressing materials.[11,12] Although longstanding surgical thinking would dictate that suction is required to create negative intrathoracic pressure and inflate a collapsed lung, this is not the case in lung volume reduction surgery. In fact, the suction appears to maintain air flow through the leaking lung and subsequently slow healing. We began treating all lung volume reduction surgery patients with "water seal only" postoperatively in early 1995. The patients appear to tolerate an apical air space from 1.5 to 7 cm without distress. Several early patients were switched to Heimlich valves to allow easy ambulation and did well, their air leaks healing and their lungs reexpanding. In a subsequent study, 25 of 107 patients (24%) experienced a prolonged air leak (>5 days) after lung reduction surgery for emphysema. The chest drainage system was replaced by a Heimlich valve to facilitate ambulation, earlier hospital discharge, and possibly healing of the air leak. Mean hospital stay was reduced 46%, to 9.1 days. The chest tubes were removed an average of 7.7 days after discharge with no ill effects noted. There were no mortalities, empyemas, or pneumonias. We concluded that the aggressive use of Heimlich valves to treat postoperative air leaks, as well as avoidance of postoperative suction, increased mobility and patient acceptance and decreased hospital length of stay. It also eliminated returns to the operating room for pleural tents or attempts to find and suture air leaks.[13]

Mechanics of Improvement

We prospectively studied the mechanism of air flow limitation in 12 consecutive patients undergoing bilateral staple lung volume reduction procedures. Patients were studied preoperatively, intraoperatively under general anesthesia with paralysis, and postoperatively. We found a significant increase in lung elastic recoil at total lung capacity as well as maximal expiratory air flow in every patient. The measured increase was detectable immediately after resection in the operating room and appeared to be a result of the change in lung elastic recoil and not chest wall compliance, where no change was realized. We have now followed these patients for up to 1 year, and the findings remain consistent, although there does appear to be some deterioration toward preoperative levels over time.[15]

Conclusions

The optimal surgical technique for lung volume reduction surgery is the bilateral staple procedure. Older patients (>75 years), patients with elevated pCO_2, and patients on high-dose steroids could all receive signifi-

TABLE 2.—*Selection Criteria for Lung Volume Reduction Surgery*

Criteria	*Optimal Candidate*	*Possible Candidate*	*Noncandidate*
Symptoms	Moderate	Severe	Minimal
Anxiety	Controlled	Moderate	Severe
Depression	Controlled	Moderate	Severe
Age	<75 years	>75 years	—
Oxygen requirements	< 4 L	—	>4 L
pO_2	>50	40–50	<50
pCO_2	<55	>55	—
Pattern of Disease	Upper lobe	Lower lobe	Diffuse
FEV_1	20–40%	<20%	>50%
Total lung capacity	>120%	95–120%	<95%
Residual volume	>250%	150–250%	<150%

cant benefit from lung volume reduction surgery, and there appears to be no lower limit of FEV_1 for successful outcome. Patients with severe hypoxemia should probably not undergo lung volume reduction surgery. Patients with hyperinflation respond well to lung volume reduction surgery, although severe hyperinflation does not seem to be a requirement for significant improvement any more than moderate hyperinflation (residual volume 150 to 250%). Overall, upper lobe disease responds best, although some patients with lower lobe disease have significant improvement in dyspnea indexes despite smaller changes in FEV_1. Severe anxiety, severe depression, and failure to undergo rehabilitation correlate strongly with bad results. The selection criteria are summarized in Table 2.

Lung volume reduction surgery can provide substantial improvement for selected patients in quality of life and pulmonary function. The bilateral staple operation (either open or closed) can be performed with acceptable morbidity and mortality even in the most severely disabled patients. Long-term results and impact on survival require further studies, which should also further define patient selection criteria.

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